Carnegie Mellon University

95-733 Internet of Things
Enabling the Internet Of Things

Week 2

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Summary From Last Week: Smart and Connected Products

- IT is revolutionizing products.
- Once, solely mechanical and electrical parts.
- Now, complex systems with connectivity.
- Smart, connected products are unleashing a new era of competition.
- Some companies will ask “What business am I in ?”
- Many products will contain a computer or microcontroller and have a representation in the cloud (Digital Twin).
- This changes product design, marketing, manufacturing, and after sales service.
- This creates opportunities for rich data analytics and machine learning.
- Security and privacy concerns are significant but will probably not be a show stopper.
- Lessons learned from the WWW may help us achieve a more interoperable IOT.
- We can build a Web of Things.

Building a web of things

It’s about more than smart, connected products.

Let’s revisit our traditional objects

BLE Tag

URL

BLE Tag

URL

NFC Tag

URL

QR Code

URL

What good are the URL’s?

Each URL can be dereferenced and used to request additional information.

A web service will exist at the URL, allowing us to, say, purchase a ticket for a concert.

Of course, these objects may be smart and connected as well.

Quiz: in the video that follows, identify the objects that use tags.

https://www.youtube.com/watch?v=1yaLPRgtlR0&feature=youtu.be

The BLE beacons shown in the video have not taken off to the degree that Google once hoped. But URL transmission through NFC and QR-Codes is widely used.

Tagging Passive Things (1)

- Passive things may not be suitable for direct wired or wireless connections to the internet.
- For these things, we need perhaps a tag, a smartphone and a proxy web service.
  See the NFC tag on the movie poster in the video.
- Three popular approaches to passive tagging
  (1) UHF RFID < 10 ft not successful in practice
  NFC is a form of RFID (the user must be very close to engage)
  (2) Optical tags (Quick Response Codes) and barcodes
  Require a camera and an application. That may be a drawback.
  They may yield text, numbers, or URIs.

May also be used to hold a public key.
Why might a person or thing advertise a public key?

Ransomware – pay a bad guy.

Pay a device for usage.

See GS1 Digital Link: using bar codes to provide URL's.
Are we interested in from farm to table tracking?
See https://www.youtube.com/watch?v=jrgr7A6jBbo

Tagging Passive Things (2)

(3) Bluetooth Low Energy (BLE)

Uses less energy than Bluetooth classic
A BLE device might last weeks or years without a new battery or recharge
The BLE protocol optimized for small bursts of data exchange – ideal for sensors or actuators.
Bluetooth classic provides high bandwidth for audio streaming.
All modern smart phones support
Advertise a packet, perhaps a URL, every second
BLE is used by iBeacon (Apple) and Eddystone (Google, deprecated)
See Web Bluetooth to interact with BLE device from Javascript
May be used with Geo Fencing applications

GeoFencing and BLE

- The user has a mobile application installed on a phone.
- The application may be running in the background.
- The application detects user locations based on:
  - Native positioning (20 to 50 meters)
    - GPS signals and WiFi and cellular data
  - Bluetooth positioning (2 meters)
    - BLE Beacons in the local environment or indoors
- The phone detects any crossings of a virtual fence.
- The phone triggers actions: alert the user, notify a business owner, notify a government, notify a competitor etc..

CovidSafe (Australia) and BLE contact tracing

- Install government application from Apple or Google.
- Register some PII with the cloud service (AWS).
- The PII is encrypted and stored by the service.
- The app uses Bluetooth to detect others with the application.
- The two applications exchange anonymized ID’s.
- If someone is infected, they receive a unique code from health official. This code allows the application to upload the list of anonymized ID’s.
- Those others are notified of the past contact.

From New South Wales Government

Helping customers to use the NSW Government QR Code

1. Download and display your unique NSW Government QR Code poster. You must not alter the poster in any way.
2. Display the QR Code where it's easy to see and easy for customers to scan.
3. Confirm the customer has successfully checked in (look for the green tick on the confirmation screen).
4. https://www.nsw.gov.au/covid-19/rules/check-in/service-nsw-app

Edible Tags to solve a major worldwide problem

It is estimated that as many as 250,000 children die per year due to counterfeit drugs.

Edible 'Security Tag' to Protect Drugs From Counterfeit January 16, 2020

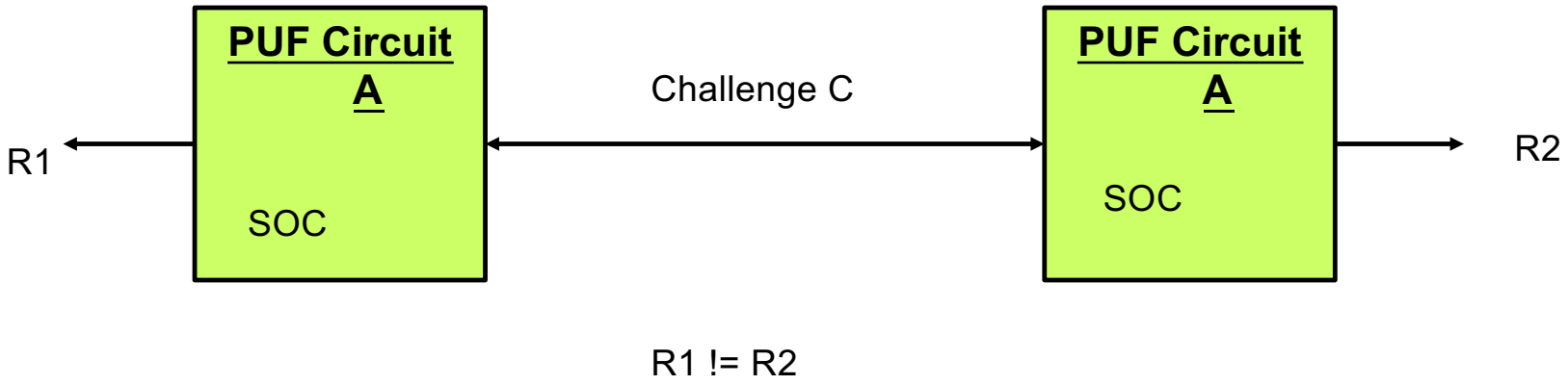
Purdue University News

Kayla Wiles

Purdue University researchers have developed a consumable "security tag" that can be embedded into medications to thwart drug counterfeiters. The tag serves as a digital signature for each pill or tablet, using physical unclonable functions (PUF). The researchers created an edible PUF, in the form of a thin, transparent film of genetically combined silk and fluorescent proteins; illuminating the tag with a light-emitting diode (LED) causes fluorescent silk microparticles to glow in a distinct random pattern in cyan, green, yellow, or red. The resulting image contains digital bits that form a security key to confirm the drug's authenticity. Purdue's Jung Woo Leem said, "Our concept is to use a smartphone to shine an LED light on the tag and take a picture of it. The app then identifies if the medicine is genuine or fake."

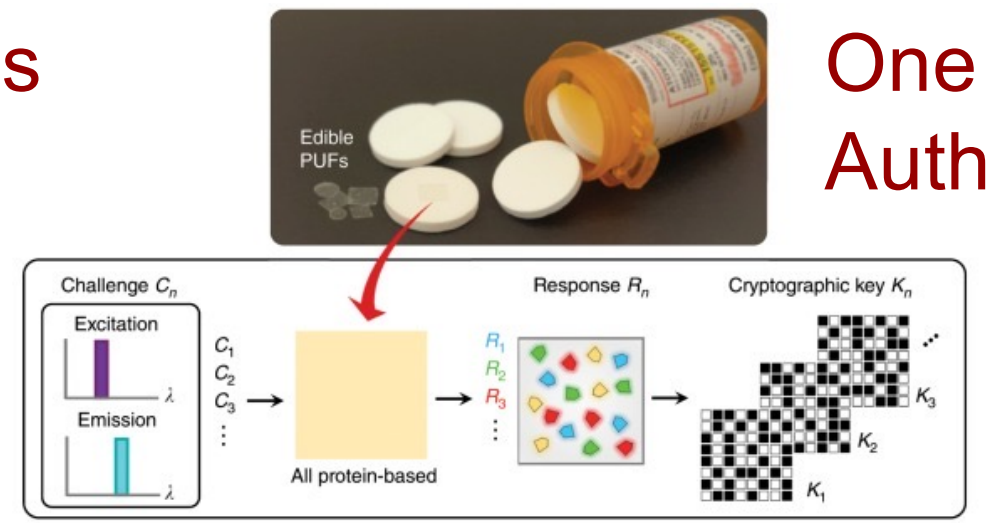
I

Physical Unclonable Functions (PUFs)



The manufacturing process introduces small variations in the product.
The PUF Circuit is able to measure the variations.

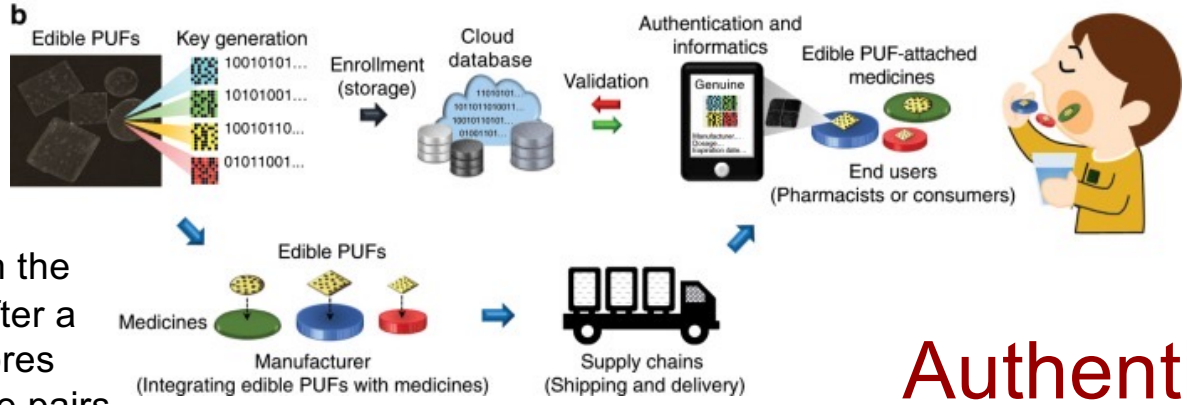
Edible Tags



One Time Authentication

Four challenges at
64 bits per challenge =
256 bit key

Enrollment



Delete the key from the secure database after a scan. Database stores challenge, response pairs.

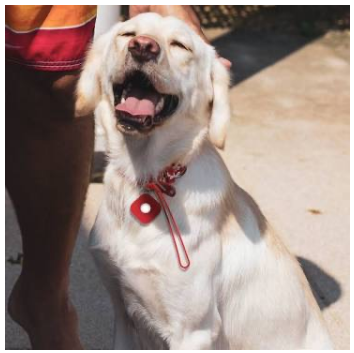
Authentication

Norman Joseph Woodland (1921-2012)

- Developed the format which became the ubiquitous the Universal Product Code (UPC) of product labeling and check-out stands.
- UPC is a bar code used for fast identification.
- The bar codes are placed on nearly every product sold.
- Also used on labels for shipping and tracking applications.
- An estimated 5 billion bar codes are scanned every day.

Apple AirTag

- AirTags don’t contain cellular or wi-fi internet connections. They are able to communicate locally with Bluetooth or Ultra Wide Band.
- An iPhone knows where it is. A Bluetooth signal can be pinpointed within about 5 meters from the iPhone. Using Ultra Wide Band technology, the tag can be pinpointed within 5 to 10 centimeters.
- The connected device (an iPhone) sends the AirTag and location information to Apple. Apple tells the owner where the Airtag is.
- Location reports go back only to the AirTag’s owner; nobody else sees them.
- AirTags work everywhere there’s a nearby iPhone.
- If you have only an Android, you can read NFC from the device and return the lost dog.



Apple AirTag and Stalking

- Stalker places an AirTag in your backpack.
- Off you go.
- Stalker views your location on a map.
- Your iPhone may notice an AirTag nearby with no local owner and provide reports to you.
- Suppose that you only own an Android - your Android will not notice the stalker's AirTag.

Short Course on Networks

- Any device, in practice, that connects directly to the internet requires a physical Ethernet, Wi-Fi radio, or cellular modem. All of these increase cost and power consumption.
- The wireless coverage of a cell tower is measured in miles.
- The wireless coverage of Wi-Fi is measured in yards.
- We can use constrained networks for low or no power devices.
- We can use one bridging device that supports Wi-Fi and enables simple peripheral IoT devices to talk to the bridge.
- UWB (not Verizon 5G) coverage is measured in 10's of yards. Not new.
- BLE wireless coverage is measured in feet.
- NFC wireless coverage is measured in centimeters.
- NFC requires user attention and engagement. BLE does not.
- BLE Beacons continually transmit a discovery signal to be received by a BLE enabled device - Smartphone
- NFC Tags communicate only when close to an NFC enabled device - Smartphone
- BLE beacons have been around since 2006
- NFC is based on RFID and RFID has been around since the 1940's.

From: Mobile Payments Today

Building the Web of Things

- Things need to be identified.
- At a low level, IPV6 supports 128-bit addresses.
- That's a lot of addresses.
- At a higher level, identify things with Web URI's (URL's and URN's).
- URI = Uniform Resource Identifier = Location and/or name
- URN = Uniform Resource Names = Name
- URL = Uniform Resource Locators = Location
- URN's and URL's are URI's.
- URL's in conjunction with DNS route and connect to services.

Building the Web of Things

- Design the IoT as an extension of the World Wide Web.
- Build a physical web = web technologies + IoT.
- Web technologies include URL's, XML, JSON, HTTP, Websockets, REST, CoAp, and TLS .
- To overcome scale and complexity, preferentially discover things nearby.
- Useful processing may be performed on the edge.
- Consider peer to peer connections and cloudlets.
- Consider the integration of devices that have little or no processing capabilities.

The Physical Web

- The Physical Web associates People, Places, and Things with web pages or services.
- Take seriously the use of proximity beacons or tags.

The Physical Web

An Eddystone Beacon using BLE

RadBeacon Dot for The Physical Web

From the advertisement:

“Simply include the PhysicalWebURL you will like your beacon configured for, and we will get the beacon configured prior to shipping. To place an order for beacons with different URLs, please follow the steps below:”

Waze use Eddystone and iBeacon for GPS inside tunnels.

The Web of Things

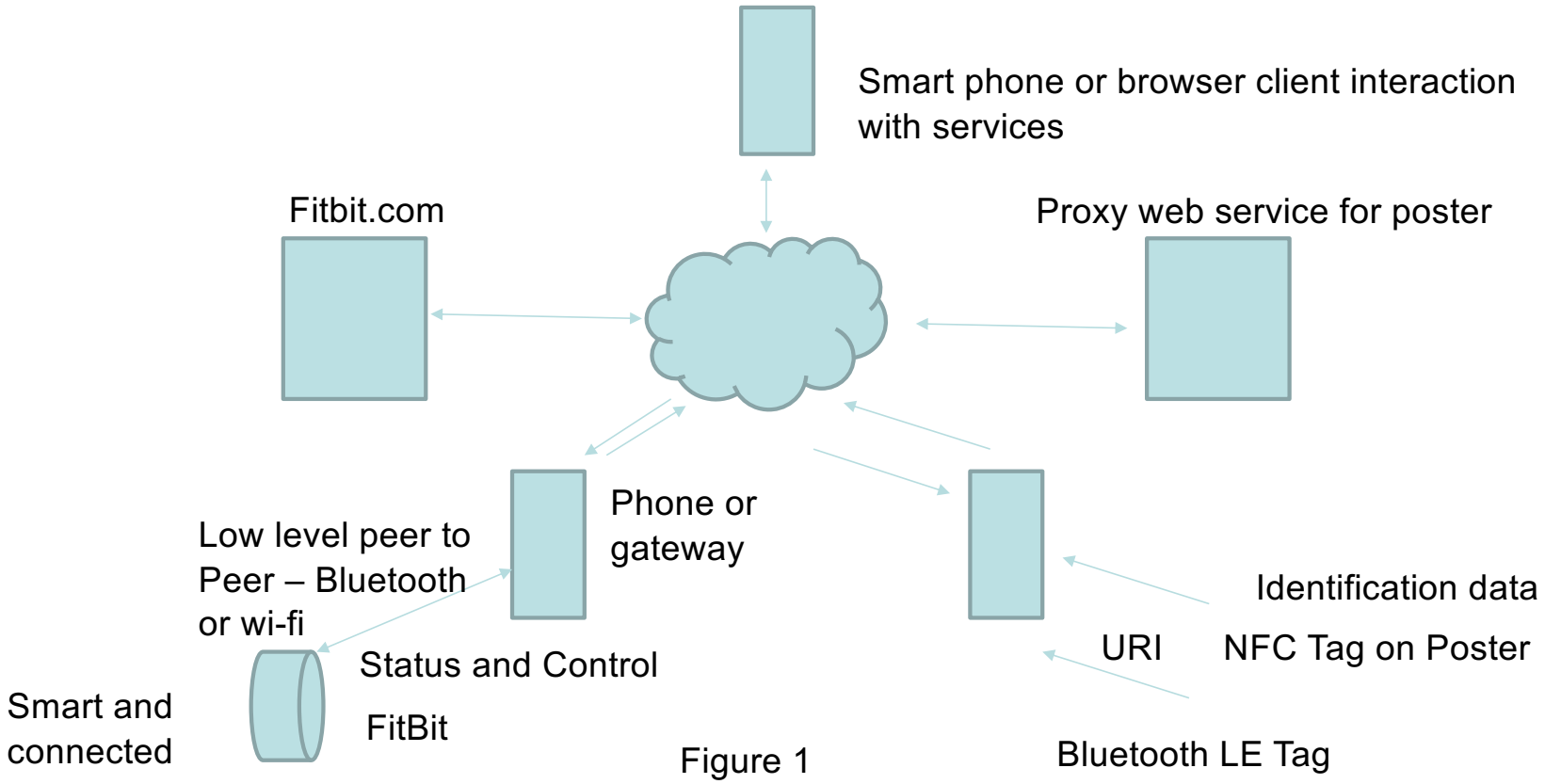


Figure 1

Edge Computing

- An innovative solution to latency problems (using the cloud) is edge computing.
- Cloudlets (from CMU) are an important example:
  A cloudlet is dynamically provisioned with software and services.
  Is nearby and holds only soft state.
  Is more powerful than local devices.
- An important edge API is IBM's Apache Edgent. Apache Edgent is a lightweight and embedded streaming analytics runtime that analyze events locally, on the edge of your system, sending only relevant events downstream. (From Apache Edgent)
- Node-RED might also be appropriate running in a cloudlet or on the edge.

Client Server or Peer to Peer

1) Simple device and powerful cloud service. (a centralized model)
2) Complex device on its own (perhaps involved in a peer to peer network)

Tradeoffs	Complex Device	Simple Device	Cloudlet
Latency	Low	High	Low
Security	Low	Higher	Higher
Privacy	High	Lower	Lower
Cost	High	Lower	Lower
Management	High	Low	Low
Autonomy	High	Low	Low

With respect to security, the use of cloud providers is no guarantee. There is a possible false sense of risk transfer with cloud provider or outsourcing.

Proximity Sharing

- One nearby device has a capability needed by another (need a big screen?)
- Companies may not adopt standards so they can lock you in and dominate.
- European banking PSD2 regulates API's in order to increase competition.
- Not easy. For proximity sharing we need:
  Discovery,
  Trust,
  Connection through standard data formats and protocols.

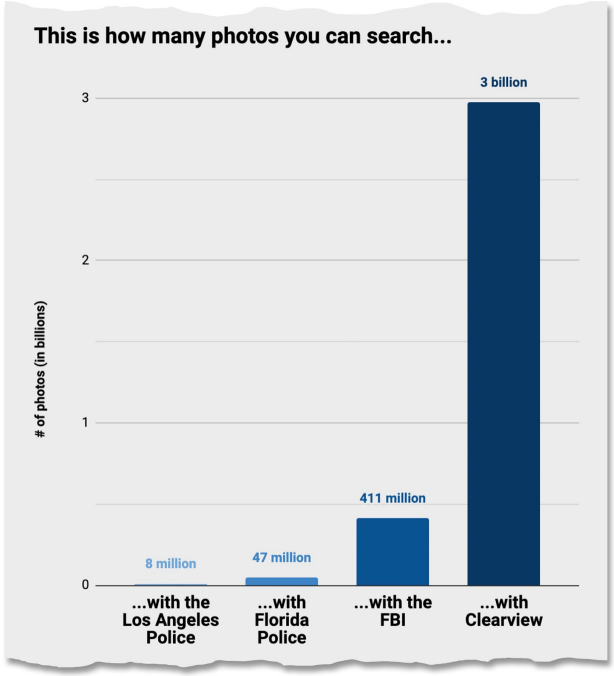
The Physical Web

What if a Thing is not smart, connected, or tagged?

San Francisco bans facial recognition technology. May 14, 2019

The Physical Web

What if a Thing is not smart, connected, or tagged?



Facial recognition application
From New York Times January 2020

When the Clearview app looks for matches, it includes photos from the web. This is a privacy concern. You no longer need to have a prior arrest.

One reason that Clearview is catching on is that its service is unique. That's because Facebook and other social media sites prohibit people from scraping users' images — Clearview is violating the sites' terms of service.

"It's creepy what they're doing, but there will be many more of these companies. There is no monopoly on math," said Al Gidari, a privacy professor at Stanford Law School. "Absent a very strong federal privacy law, we're all screwed."

Summary

- The World Wide Web is an excellent guide to building an interoperable IoT.
- Interoperability, context awareness and machine learning will lead to very smart devices and many things being web present.
- Security and privacy problems will continue but will not stop the show.

- Bibliography:
- “How Smart Connected Products are Transforming Competition”
  Harvard Business Review
  https://hbr.org/2014/11/how-smart-connected-products-are-transforming-competition
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  IEEE 2015
  http://www.andrew.cmu.edu/user/mm6/95-733/iot/Enabling_the_Internet_of_Things.pdf